Cost-Effectiveness Analysis for Wind Energy Projects

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***Abstract*-This paper presents the cost effectiveness indicators or methods for economic cost analysis applied to wind energy projects. It discusses about Levelezed Cost of Energy (LCOE), Total Life-Cycle Cost (TLCC), Net Present Cost (NPC), Levelized Electricity Generation Cost (LEGC) and Unitary Present Average Cost (UPAC). For each indicator studied is pointed out its bottlenecks about the application in evaluation and management of wind energy projects directly. However, it is important to consider the purpose and scope of a particular analysis at the outset because this will prescribe the course to follow. The perspective of the analysis is important, often dictating the approach to be used. Also, the ultimate use of the results of an analysis will influence the level of detail undertaken.**

Keywords-Cost-Effectiveness; Economic Analysis; Wind Energy; WECS

I. INTRODUCTION

Cost analysis of the electricity supplied by wind energy conversion systems (WECS) is a rather difficult task requiring the estimation of output power generation as well as the cost of the WECS, in addition to the analysis of the wind distribution parameters. Power generation of the WECSs is closely related not only to the system's performance but also to operating conditions, which means the wind characteristics of the site, as well. Therefore, the selection and installing of suitable wind electric generator to produce electrical energy economically in the windy areas requires a number of activities that include the investigation of the source, feasibility assessment etc.

The economic cost analysis of wind power is dependent upon the following factors: *(i)* available wind resource, *(ii)* installed capital costs and cost of capital, *(iii)* operation and maintenance costs, *(iv)* wind integration costs, *(v)* transmission line interconnection and grid upgrade costs, *(vi)* value of available subsidies or incentives, and *(vii)* willingness of customers to pay a premium for wind energy.

A. Specific Measures of Economic Performance for Energy Projects

TableI EXAMPLE OF NET CASH FLOW FOR ECONOMIC PERFORMANCE IN ENERGY PROJECTS (NPV METHOD)

Cash Flows	**Period (years)**						**NPV$_{years}$**
	0	1	2	3	4	5	
Alternative 1 Net Cash Flow	-100	20	40	30	50	10	14,1
Alternative 2 Net Cash Flow	-50	20	25	30	-	-	11,4

Source: [2].

The costs levelized (or revenue→ revenues levelized) is a technique to compare investment alternatives (such as renewable energy projects), involving different amounts of capital (i.e., different sizes) and/or different time periods with different life-cycles. Applying the NPV method is done implicitly on assumptions necessary reinvestment in renewable energy projects. These implicit assumptions can be avoided by smoothing of cash flows: even involves the calculation of steady cash flow, net present value (NPV) is equal to a given cash flow variable [1]. Suppose that two investment alternatives for renewable energy projects have the following net cash flow per period, as shown in Table I.

The alternative 1 implies a higher initial investment (capital requirements) and provides higher absolute return than alternative 2. Alternative 2 has only a small initial investment, but also shorter lifetime (3 versus 5 years). It is difficult to make a direct comparison between the two projects. In calculating the NPV of the project (with a discount rate of 10%) results in NPV = 14.1 for an alternative 1 and NPV = 11.4 to alternative 2. For the NPV rule suggests that an alternative 1 is chosen. The levelizing of cash flows (net) is to find a constant amount g during the life of the project NPV with this flow in equal amounts g to become equal to the NPV of the original project, as shown in Fig. 1.

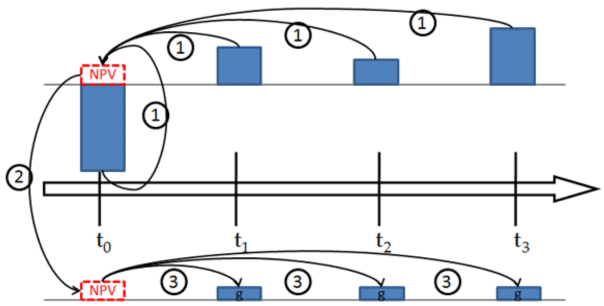

Fig. 1 Schematic of the cash flows levelizing process for renewable energy projects [2].

This amount g (also called "annuity") is calculated using the formula below:

$$g = NPV \times UCRF = NPV \times \left[\frac{i(1+i)^n}{(1+i)^n - 1} \right] \quad (1)$$

The UCRF (Uniform Capital Recovery Factor), is the factor by which the NPV must be multiplied to reach the constant value g given discount rate i for a series of n periods. In the example in Table 6, the alternative creates an annuity of 3.73 (in monetary units). The five cash inflows of 3.73 are equal to a NPV of 14.1, exactly equal to the NPV of cash flows of the project plan (including initial investment). Alternative 2

generates annuity of 4.58 (in monetary units). By comparing the potential of their projects to generate stable cash flows, the alternative 2 should be higher than the alternative 1.

Annuities are not specific to renewable energy projects. The concept LCOE is used to compare the different alternatives of energy production. Revenues are fixed and equal between these alternatives (e.g., because the price is set by the regulator and does not depend on the technology used to produce energy, then the alternatives differ only in their costs (cash flows of revenues are equal to all alternatives) [3].

The above concept is applied only to cash outflows (costs). The sum of all costs involved in the project during its full life cycle (Total Life Cycle Cost - TLCC) are discounted to present value and converted into a stream of equal cash outflows for each year of the project ("annuity negative") . If the value is divided by the annual amount of energy produced, the result is called the Levelized Cost of Energy (LCOE - Levelezed Cost of Energy). The LCOE is assigned each unit of energy produced (or saved) by the project during the analysis period is equal to the TLCC when discounted to the base year (period 0). The LCOE can be used to rank different alternatives for production (or consumption) of energy, as shown in Fig. 2.

Technology	LCOE, in 2005 $/kWh
Wind	$.028
Landfill Gas	$.030
Advanced Nuclear	$.035
Scrubbed Coal	$.044
Conventional Combined Cycle (CC) Gas/Oil	$.050
Biomass	$.050
Advanced CC with Carbon Sequestration	$.069
Conventional Combustion Turbine	$.077
Solar, PV (30%)	$.235
Solar, PV (10%)	$.310

Fig. 2 Values in $/kWh LCOE (Levelezed Cost of Energy) in 2005 for various conventional and renewable technologies [3].

B. *Levelezed Cost of Energy*

The Levelezed Cost of Energy (LCOE) is the real cost of production of kilowatt-hours (kWh) of electricity. Includes the total construction, central production costs of the power station during its economic lifetime; financing costs, return on capital and depreciation. Costs are leveled in current monetary values, or adjusted to eliminate the impact of inflation. The LCOE is what it would cost the owner of the facility to produce one kWh of energy. For electricity production, the LCOE is a method to compare renewable energy technologies adopted to produce electricity. The model LCOE most known and used in energy projects by the National Renewable Energy Laboratory [4]. The calculation method is defined below.

$$LCOE = \frac{FCR \times ICC + LRC}{AEP_{net}} + O\,\&\,M + PTC \tag{2}$$

Where: FCR≡ Fixed Charge Rate; ICC ≡ Initial Capital Cost; LRC ≡ Levelezed Replacement Cost; O&M ≡ Operations and Maintenance; PTC ≡ Production Tax Credit and AEPnet ≡ Net Annual Energy Production. The calculation of LRC can be accomplished with the equation 3, where MR Machine Rating [3].

$$LRC = \frac{\$}{kW} \times MR \tag{3}$$

For correct analysis of the leveled cost of energy, the net annual energy production of the wind farm is given by equation 4. The availability is defined as the ratio of hours the wind system is capable of producing energy relative to the number of hours during the study period and losses represent loss of matrix, dirt on the blades and ice formation, the central production downtime for maintenance and miscellaneous system losses in production and distribution of energy to the electric grid [5].

$$AEP_{net} = AEP_{gross} \times \text{Availability} \times (1 - losses) \tag{4}$$

Where: AEPgross ≡ Annual Energy Production.

The LCOE was adopted by the United States Department of Energy in the Low Speed Wind Turbine Program (LWST) and makes reasonable approximation of the COE (Cost of Energy), which is estimated by the potential investor to consider the reliability of the equipment to determine AEP (Annual Energy Production), O&M (Operations and Maintenance) and LRC (Levelezed Replacement Cost). The AEP is affected by the availability of equipment due to the shutdown of wind turbines due to scheduled and unscheduled maintenance. The costs of O&M consist of programmed costs (preventive) and costs unscheduled (repair) maintenance, including costs for replacement parts, supplies, manpower, leases (royalties) of land, among other expenses arising from the operation of a wind farm.

II. FIXED CHARGE RATE

The capital cost component of COE is determined by the spread of installed capital cost over the lifetime of the project done in a linear basis over the years through the FCR (Fixed Charge Rate). The FCR is a percentage of the cost of installed capital costs including debt service (financing costs) allocated to each year of the project. The component of the cost of capital is analogous to a payment of fixed rate mortgage of a house, or fixed amount per pay period during the term of the debt. The analysis period may be the life of a physical plant for the production or lifetime for accounting purposes. The lifetime of a wind farm ranges from 20 to 30 years, while lifetime used for financial accounting purposes may be smaller [2], [6]. The FCR is the annual value for each monetary unit of initial capital cost needed to fully cover the initial capital cost, return on equity and debt, and other overheads. The fee is charged from a hypothetical project, spread over cash flow. The current base model, FCR must include funding for construction, financing rates, return on equity and debt, amortization of equipment and facilities, tax revenue and profits all on an annual basis [4].

III. INITIAL CAPITAL COST

The initial capital cost (ICC) is the sum of the cost of wind power system and the cost structure of the wind farm. Not included is cost of financing the construction or financing rates, as they are calculated and added separately through the FCR. Nor does it include the costs of the reserve fund for debt service (charges for financing costs). This cost measure includes all the

planning, equipment acquisition, construction and installation costs of the wind system, leaving the wind farm ready to operate. This cost includes wind turbine towers and delivered and installed on site along with all maintenance, electrical system and other infrastructure support. For a wind farm, the cost of installed capital should include the system of collection of electricity which extends from each wind turbine to the substation and point of interconnection with the grid. Depending on the policy and practice of grid administrator and distributor, the electrical system may or may not be included in the cost of capital [2]. The ICC includes costs for buildings to support the operation and maintenance, the initial stock of spare parts and maintenance of diagnostic equipment. Other costs should be included as costs of pre-construction planning, including assessment and analysis of wind resources, surveying, and consultancy for obtaining financing. The installed capital cost of a wind farm includes the following elements [1]:

- Assessment and analysis of wind resources;
- Construction of service roads;
- Construction of foundations for wind turbines, infrastructure to mount transformers and substations;
- Purchase of wind turbines and towers with local delivery and installation;
- Construction and installation of wind sensors, able to communicate wind turbine units for controls;
- Construction of the power reception system, including wiring of each wind turbine for the mounting of the transformer and deck mount transformers for the substation;
- Construction of facilities needed for operations and maintenance during the regular operation of the wind farm;
- Construction and installation of the communication system of wind farms to support the command and control data flow from each wind turbine to a central facility operations;
- Integration and verification of all systems for proper operation of the wind farm;
- Commissioning for wind farm period of decommissioning.

IV. LEVELEZED REPLACEMENT COST

Depending on the details of the project, the major review of the wind turbine occurs every 5, 10 or 15 years. The review focuses on the large gears, bearings, seals and other moving parts. Usually the nacelle and its machinery are removed from the tower and transported to the plant maintenance garage of the wind farm. Often, removal of the nacelle and equipment is replaced immediately by all already rebuilt [3]. The replacement of the blades of wind turbines is an example of this category of frequent replacement of subsystems. Since these costs occur at intervals of several years and infrequent during each year, correct accounting for these costs requires annual exercise of funds (working capital). The aim is to make funds available when needed to repair or total replacement of occurrence. The exercise involves calculating the net present value or even to allocate costs for review and replacement on an annualized basis consistent with other cost elements [1].

V. OPERATIONS AND MAINTENANCE COST

The costs of operations and maintenance (O&M) include costs normally associated with recurrent routine operation of the plant installed. The O&M costs do not include overtime worked or infrequently, such as major repairs of wind turbines and other systems. These costs are included in the cost component LRC (Levelezed Repalcement Costs). Most of the O&M costs is associated with maintenance and generally grouped into three categories [7]:

- Cost of unscheduled visits, but statistically predictable, routine maintenance visits to troubleshoot the operation of wind turbines;
- Scheduled preventive maintenance costs for wind turbines and energy collection system;
- Costs of major repairs and replacements scheduled subsystems of wind turbines.

The first two costs occur during the course of a year in operation and are included in the cost component of O&M. The third occurs at intervals of 5, 10 or 15 years and involves financial year over the next few years, therefore, is included in the cost component LRC. The purpose of preventive maintenance is to replace components and reform systems that have finite lifetime, generally smaller than the projected life of the turbine. Tasks include periodic inspections of equipment, lubricating oil and filter changes, calibration and adjustment of sensors and controllers, replacement of consumables such as brake pads. The cleaning of the blades in general, fits into this category. The specific tasks and frequency are usually explicitly defined in the maintenance manuals provided by the manufacturer of the turbine. The costs associated with planned maintenance can be estimated with reasonable accuracy, but may vary according to labor costs location, location and accessibility. The scheduled maintenance costs also depend on the type and cost of consumables used [8]. The unscheduled maintenance should be anticipated in any proposed wind energy production. Commercial wind turbines contain a variety of complex systems that must function correctly for the turbine work and get best possible performance. Failure or malfunction of the smaller component (subsystem), it often shuts down the turbine and require the attention of maintenance professionals. Unplanned costs can be separated into direct and indirect costs. Direct costs associated with labor and equipment needed for repair or replacement and consumables used in the process. The result of the indirect costs associated with the revenue lost due to stop the turbine. Depending on the details of ownership and location of the wind farm, there may also be costs associated with negotiating land use agreements, contracts, power purchase agreements and access to transmission and distribution of energy produced [9]. Besides the cost of operations and maintenance, spare parts and other maintenance items in the cost element of O&M may also include:

- Taxes on property where the wind farm operates;
- Payment of land use;
- Miscellaneous insurance;
- Access to transmission and distribution rates;
- Management fees and general and administrative expenses.

The values of cost of operations vary with the situation. The tax structure is where the wind farm contract, land use, insurance rates and other fees vary from location to location and installation of wind farms to another. In comparison to maintenance costs, operating costs are typically very small relative to the cost of production of a central power generation [7].

VI. PRODUCTION TAX CREDIT

The Production Tax Credit (PTC) is a type of public incentive, usually granted by the Federal Government for the renewable energy sector. This incentive is offered in the form of tax credits for producing energy for a certain period of operation of the central production of energy. The PTC is adjusted for inflation rate prevailing in the country concerned, within 10 to 15 years, falling on each MWh of renewable energy produced and sold to the distribution grid. For the production of wind power in Portugal, Decree-Law No. 33-A/2005[1] stipulates that farms that have already obtained permission to establish the date of entry into force of the law or they may obtain the license for establishment within one year after the entry into force, maintaining the current tariff of 88.20€/MWh from 2005, progressing at the rate of inflation, for a period of 15 years from the date of entry into force of that legislation. At the end of this period, the rate will converge to market price plus the premium for the sale of green certificates.

The Levelezed Cost of Energy method has drawbacks that limit its application in the assessment and management of projects in renewable energy, particularly in wind energy projects:

- The technical and economic parameters directly impact the method LCOE and should be carefully considered in the analysis of the final cost of energy produced. The dramatic reductions in LCOE occur when the wind farm wind resource is above average, or when we obtain improvements in capacity factor. This suggests that the increase in capacity factor from values below the levels of average capacity factor can lead mainly to large reductions in LCOE [10].
- The LRC that matches the costs for equipment replacement in the long term, it has been reported to be increasingly significant component to the annual cost of wind power and if it is overvalued, can inflate the cost of energy currently produced. The technological improvement in wind power can make the cost of capital is smaller in the coming years.
- The LCOE is a methodology for determining and analyzing the cost of energy production restricted to certain period of time. The fact that the analysis is for one year of production (a single unit of time) ignores gains economies of scale throughout the project life.

A. *Total Life-Cycle Cost*

The evaluation method Total Life-Cycle Cost (TLCC) method is derived from the NPV, as it takes into account only items of costs (cash outflows). The TLCC evaluates the differences in cost (and time of occurrence of costs) between project alternatives over the life cycle. Cash outflows associated with the project (alternatives) are evaluated for each period and are then discounted to present value using a discount rate as defined in the NPV approach [11]. The TLCC calculate the present value of all cash outflows (cost items), but no cash inflows (revenues). This only makes sense if:

- There is no revenue generated by the project (Note that the cost saved are recorded as revenue) or,
- Revenues are independent of the investment decision (e.g., because revenues are fixed, no matter what the investment decision is chosen).

The analysis may focus only on cash outflows. Soon the TLCC takes no account of the project income, which makes this indicator not adequate to evaluate absolute attractiveness of an investment alternative. It can be used to evaluate the relative attractiveness of alternative investments when considering the cost per unit of output as a factor of choice. By definition, the calculation of TLCC is defined by the following formula [10]:

$$TLCC = \frac{Co_1}{(1+i)} + .\frac{Co_2}{(1+i)^2} + ... + \frac{Co_t}{(1+i)^t} = \sum\left(\frac{Co_t}{(1+i)^t}\right) \quad (5)$$

Where: TLCC ≡ Total Life -Cycle Cost; Co_t ≡ Cash outflows in period t; i ≡ Discount rate and t ≡ Number of periods.

The TLCC has disadvantages that limit its application in assessing and managing projects in wind energy projects:

- The need to know the actual capital cost of the project. As the interest rate that measures the cost of capital for an investment should include the risk of the project, the task of defining the real value of capital cost is not always easy to accomplish.
- The failure to consider the project's revenues, there is interference by the revenue costs, because there are costs that are directly influenced by income, as is the case of taxes on income in energy projects that may or may not be supported by incentive programs governments on renewable energy.
- Costs are projected for the life of the project, which makes the financial cycle equal to the operating cycle of the investment, which by classical rules of accounting does not always coincide.

B. *Net Present Cost*

The Net Present Cost (NPC) of a renewable energy project is the sum of the current value of all costs during the project's interest period (generally considered its lifetime), including residual values[2] as costs. The net present cost of a project is the sum of all cost components, including [13]:

- The investment of capital or initial capital cost;
- O&M costs, excluding fuel (in case of wind);
- Costs of major replacements;

[1] Available in http://www.edpdistribuicao.pt/pt/produtor/renovaveis/EDP%20Documents/DL33A-2005.pdf

[2] It is understood by residual values, the difference between the book value of the commercial value of a fixed asset after the project lifetime. 12.Newnan, D.G. and Jerome P. Lavelle., *Engineering Economic Analysis*1998, Austin, TX.: Engineering Press..

- Energy costs (fuel costs, including other associated costs);
- Any other costs such as fees and legal fees, among others.

If a series of projects or investment options are being considered, the lowest net present cost will be the best option. By definition, the formula for calculating the NPC is defined as [14], [3]:

$$NPC = \frac{Co_1}{(1+i)} + \frac{Co_2}{(1+i)^2} + ... + \frac{Co_t}{(1+i)^t} + \frac{D_v}{(1+i)^N} = \Sigma\left(\frac{Co_t}{(1+i)^t} + \frac{D_v}{(1+i)^N}\right) \quad (6)$$

Where: NPC ≡ Net Present Cost; Cot ≡ Cash outflows in period t; i ≡ Discount rate; t ≡ Number of periods of outflows; N ≡ Lifetime of wind park and Dv ≡ disinvestment value.

The NPC has disadvantages that limit their application in the evaluation and management of wind energy projects:

- The discount rate or cost of capital remains unchanged throughout the period under review the project because the cost of capital depends on the behavior of the risk of the activity that tends to be decreasing with the years of operation and technological maturity.
- The financial indicators considered over the life of the project (inflation, discount rate, insurance, taxes, among others) also remain constant throughout the period analyzed what makes the NPC not to be influenced by the uncertainties of the economic scenario where the projects are inserted.
- The fact of considering the value of disinvestment, especially for wind energy projects, because it is capital intensive project, makes the value of the divestment is high compared to other renewable technologies. In the case of wind energy projects return higher net present cost.

C. Levelized Electricity Generation Cost

The Levelized Electricity Gereration Cost (LEGC) per kW is the proportion of the total cost over the lifetime of the project from anticipated results expressed in equivalent terms by the current value. This cost is equivalent to the average cost being paid by consumers to cover production costs included capital costs, operations and maintenance, fuel, rate of return equivalent to the discount rate. The formula used for calculating the LEGC for one unit of electricity generation is defined by IEA [2]

$$LEGC = \frac{\Sigma\left[\left(I_t + M_t + F_f\right)(1+r)^{-t}\right]}{\Sigma\left[AAR(1+r)^{-t}\right]} \quad (7)$$

Where: LEGC ≡ Levelized Electricity Generation Cost; It ≡ Investment expenditures in the year t; Mt ≡ Operations and maintenance expenditures in the year t; Ft ≡ Fuel expenditures in the year t; AAR ≡ Average Annual Revenue based on hourly production and r ≡ Discount rate; t ≡ Number of outflows periods.

By comparing LEGC for wind energy projects in different sites, it is important to define the limits of "production system" and costs that are included in it. For example, transmission lines and distribution systems should be included in the cost? Usually only connection costs to the production source for the transmission system is included as cost of production. One must be careful to delimit the border of cost analysis, what should or should not be included in the cost of energy [8]. The LEGC has disadvantages that limit application in the assessment and management of projects in wind energy projects:

- The discount rate or cost of capital remains unchanged throughout the period under review the project because the cost of capital depends on the behavior of the risk of the activity that tends to be decreasing with the years of operation and technological maturity.
- Capital costs are regarded as a lump sum at the beginning of the analysis; however there are other capital costs as major equipment installations and replacements that occur in other periods of the plant's lifetime production.
- All recurrent costs begin to accumulate from the first period and are grouped together and considered to occur at the end of the current period. By using the discount rate to update and add costs in different periods, one runs the risk of this rate is different from the rate at which raise costs and other current expenditure over the life of the project.

D. Unitary Present Average Cost

The Unitary Present Average Cost (UPAC) is significant for each year. However it is less meaningful if the evaluation period extends from the investment decision until the end of the lifetime of the plant production. The average annual cost per unit calculated for the two solutions, both technically and financially different, may be the same and be different than the interest of such solutions. To obtain the average unit cost updated, update separately charges (investment, operations and maintenance, fuel, and others) and total output during the lifetime of the plant production. Assigning charges generally updated by PVCo and annual accumulated and updated by PVsAEP, UPAC (€/kW), is given by [3]:

$$UPAC = \frac{\sum PV_{\mathrm{Co}}}{PVs_{AEP}} \quad (8)$$

Where: PVCo ≡ Present value of cash outflows and PVsAEP ≡ Present value of cumulated annual energy production.

The actualization process it means calculate the amount as payments and receipts made on various dates if made at time t = 0. To set the model to consider is necessary to establish precisely what is expected escalation for the exits and entries for cash. A fairly general model can admit that both the inputs (energy sales) and cash outflows (investment, operating costs) are irregularly spread over a period of n years of life. Although payments and receipts are distributed more or less irregularity over time, can be assumed:

- Expenditure is done on the first day of the year during which they pay,
- Revenues go into the last day of the year in which they actually receive it.

The interest and depreciation depend on the conditions of financing, accepted the same for all projects being compared. The following calculation is the average cost to date, considers itself neither interest nor amortization. Invested capital and its depreciation could never be considered simultaneously, it

would be duplication [15]. In this model of assessment of costs, cash outflows are classified as investment costs and operating expenses. The investment costs include all cash outflows arising from the physical structure of the central production (machinery and equipment, civil works, roads and access, control systems, among other things of that nature). How operating costs shall include O&M costs, fuel and other charges related to the regular functioning of the power plant. The calculation of the UPAC, starting of the equation 8, it is assumed the following parameters:

- Investment (ICC) focuses on the initial moment of the project (t = 0).
- The annual use of power (capacity factor for wind projects) installed is constant throughout the lifetime of the project.
- The O&M costs are constant over the useful lifetime and equal to $C_{O\&M.}$
- There are no charges for fuel, will be the case of small hydroelectric plants, wind farms and photovoltaic cells.
- The various charges are void or may be included in the O&M costs.

Accordingly, the UPAC is defined by:

$$UPAC = \frac{ICC(1 + C_{O\&M} \times \alpha)}{(AEP \times \alpha)} = \frac{ICC(\beta + C_{O\&M})}{AEP_s} \qquad (8)$$

Where: UPAC ≡ Unitary Present Average Cost; ICC ≡ Initial Capital Cost; CO&M≡ Operations and Maintenance costs and AEPs ≡ Cumulated annual energy production.

For those factors $\alpha = \left[\frac{(1+i)^t - 1}{i(1+i)^t}\right]$ and $\beta = UCRF = \left[\frac{i(1+i)^t}{(1+i)^t - 1}\right]$,

Where: i = interest rate and t = number of outflows or lifetime of the project.

The UPAC has disadvantages that limit its use in evaluating and managing projects in wind energy:

- Capital costs (ICC) are considered as a fixed sum at the beginning of the project; however there are other capital costs as major equipment installations and replacements that occur in other periods of the plant's lifetime production.
- The capacity factor is not fixed throughout the period of operation of the project (lifetime), which makes the wind production variable over the years. By oscillating energy production, there is also fluctuation in wind energy revenues and costs.
- The O&M costs are not fixed over the lifetime of the project. The maintenance contracts for wind farms are defined according to the warranty period given by equipment manufacturers. The duration of maintenance contract outside the manufacturer’s warranty is 5 to 12 years, yet the life of the wind farms are for at least 20 years.

E. Peculiarities in the Cost Analysis of Wind Energy Projects

The adoption of standardized methodology for calculating the cost of wind energy projects is necessary in the efficient management of a wind farm. Some approaches can be used for economic assessment in various contexts, to reflect the criteria and priorities of different economic agents involved in the venture.

For the correct definition and calculation of the cost of one unit of energy produced by a central production is essential to characterize the boundaries of the project under study. It is important to compare the power plants meet the cost of energy produced in isolation, but may not reflect the total economic impact of new power when connected to the network within an existing electrical system. It is important from the standpoint of the producer to estimate the cost of producing one unit of energy for the management and evaluation of the project as a business unit must ensure that economic return for the investor/manager [16]. The average cash cost methodology for the series of costs to present values at a given base year by applying the discount rate. The discount rate considered appropriate for the energy sector may differ from country to country, and in the same country, from technology to technology. Applying the discount rate takes into account the time value of money, or an amount earned or spent in the past or future, has the same value as the same amount (in real terms) gained or spent on this. The discount rate may be related to rates of returns that can be earned on investments typical, which may be a fee required by regulators incorporating the provision for financial risks and/or derived from national macroeconomic analysis. Despite the investment option not to depend entirely on how it is financed, as it should be profitable by itself, funding may influence the attractiveness of the project. This is especially true for renewable energy projects. How often is very capital intensive and require large amount of initial debt and equity. The financial conditions for such a loan, becoming an important factor in the project evaluation [6].

VII. SUMMARY AND CONCLUSIONS

The objective of an economic analysis is to provide the information needed to make a judgment or a decision. The most complete analysis of an investment in a technology or a project requires the analysis of each year of the life of the investment, taking into account relevant direct costs, indirect and overhead costs, taxes, and returns on investment, plus my externalities, such as environmental impacts, that are relevant to the decision to be made. However, it is important to consider the purpose and scope of a particular analysis at the outset because this will prescribe the course to follow. The perspective of the analysis is important, often dictating the approach to be used. Also, the ultimate use of the results of an analysis will influence the level of detail undertaken. The decision-making criteria of the potential investor must also be considered.

Among the economic indicators presented in this paper, as shown in Table II, it is possible to summary up these points:

- LCOE is recommended for use when ranking alternatives given a limited budget simply because the measure will provide a proper ordering of the alternatives, which may then be selected until the budget is expended. LCOE is not recommended when selecting among mutually exclusive alternatives because differing investment sizes.
- TLCC is not recommended for economic evaluation to decide whether to accept or reject an investment because TLCC provides no frame of reference for what are acceptable and unacceptable costs, and TLCC does not address benefits and

returns. TLCC can be used for ranking or selecting among mutually exclusive alternatives that provide exactly the same benefits and returns.

- NPC is not recommended for economic evaluation to decide into different size investment because this indicator takes into consideration the value of disinvestment, especially for wind energy projects, as it is capital intensive project. In the wind energy projects return higher net present cost.

TABLE II

OVERVIEW OF METHODS OF ECONOMIC COSTS EVALUATION TO SPECIFIC FEATURES AND DECISIONS

	Methods of economic costs evaluation				
	LCOE	TLCC	NPC	LEGC	UPAC
Significant investments (negative net cash flow) after first return	Possible	Possible	Possible	Not useful	Not useful
Investment subject to regulation	Possible	Possible	Possible	Possible	Possible
Project-specific debt-financing needed	Possible	Possible	Possible	Possible	Not useful
Social costs (externalities)	Possible	Possible	Preferred	Not useful	Possible
Taxes	Possible	Possible	Possible	Possible	Possible
Select from mutually exclusive alternatives	Not useful	Possible	Preferred	Possible	Possible
Ranking (Limited budget)	Preferred	Possible	Possible	Possible	Possible
Risks	Possible	Possible	Possible	Possible	Possible

Source: Adapted from [2],[3].

- LEGC is not recommended for economic evaluation to decide about significant investments and social costs (externalities) because the border of cost analysis is not specific and can change its dimension depends on the analyst conception. In wind energy projects this border can be totally different.
- UPAC is not recommended for economic evaluation to wind projects because this indicator takes into consideration the ICC and O&M costs fixed in the beginning of the project. Wind projects differ from it due to its project's nature.

This paper cannot provide an exhaustive and complete exposition of the theory and practical pitfalls of particular economic methods. No analysis will be valid if it is not based on sound and consistent data. The economic measures described in detail in this paper can be used to compare alternative investments or wind projects. These methods can be used as comparison tools.

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